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Novel Ensemble Atmospheric Modeling Techniques for the Simulation of Large-Scale Dispersion

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Savannah River National Laboratory

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Mesoscale Meteorological Model Ensemble

- Running multiple simulations of the same time period with the same model
- Used to estimate a range of model variability
- Usually created by perturbing the model initial conditions
- Can also be created by perturbing the model *parameters*

Project Goal

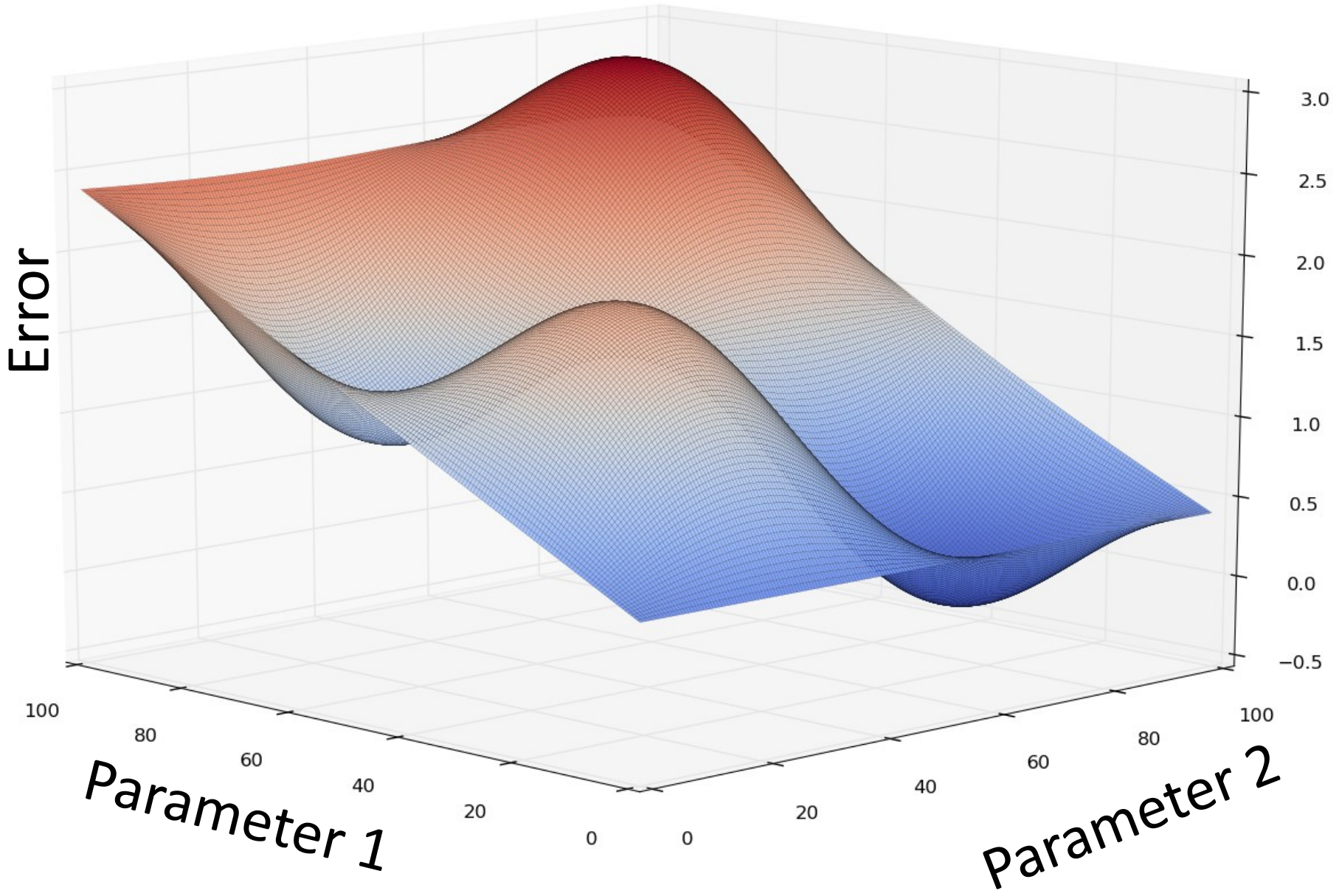
- Simulate a tracer release using the Regional Atmospheric Modeling System (RAMS) coupled to the HYSPLIT dispersion model

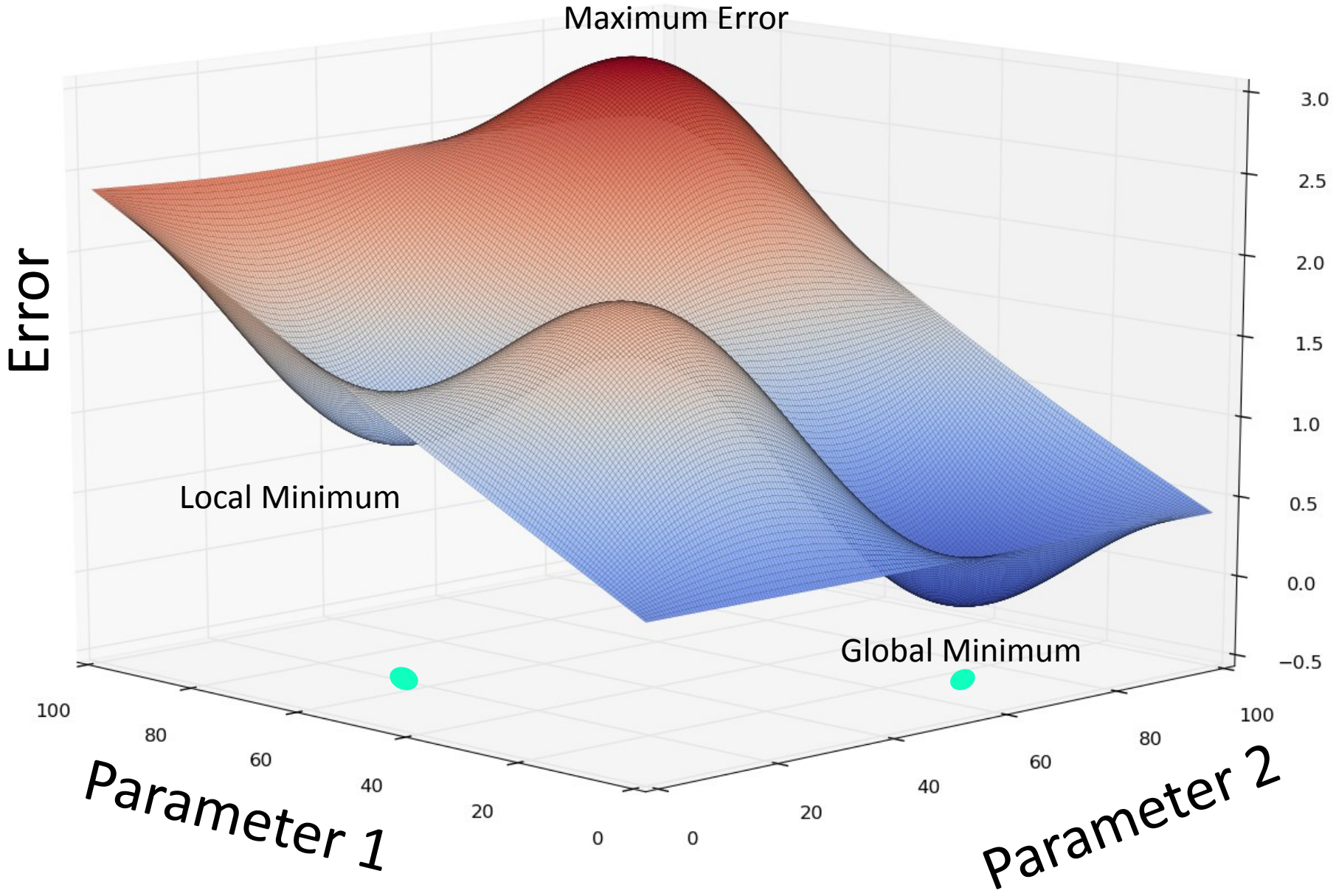
- Apply **adaptive programming** to find the best RAMS model parameters

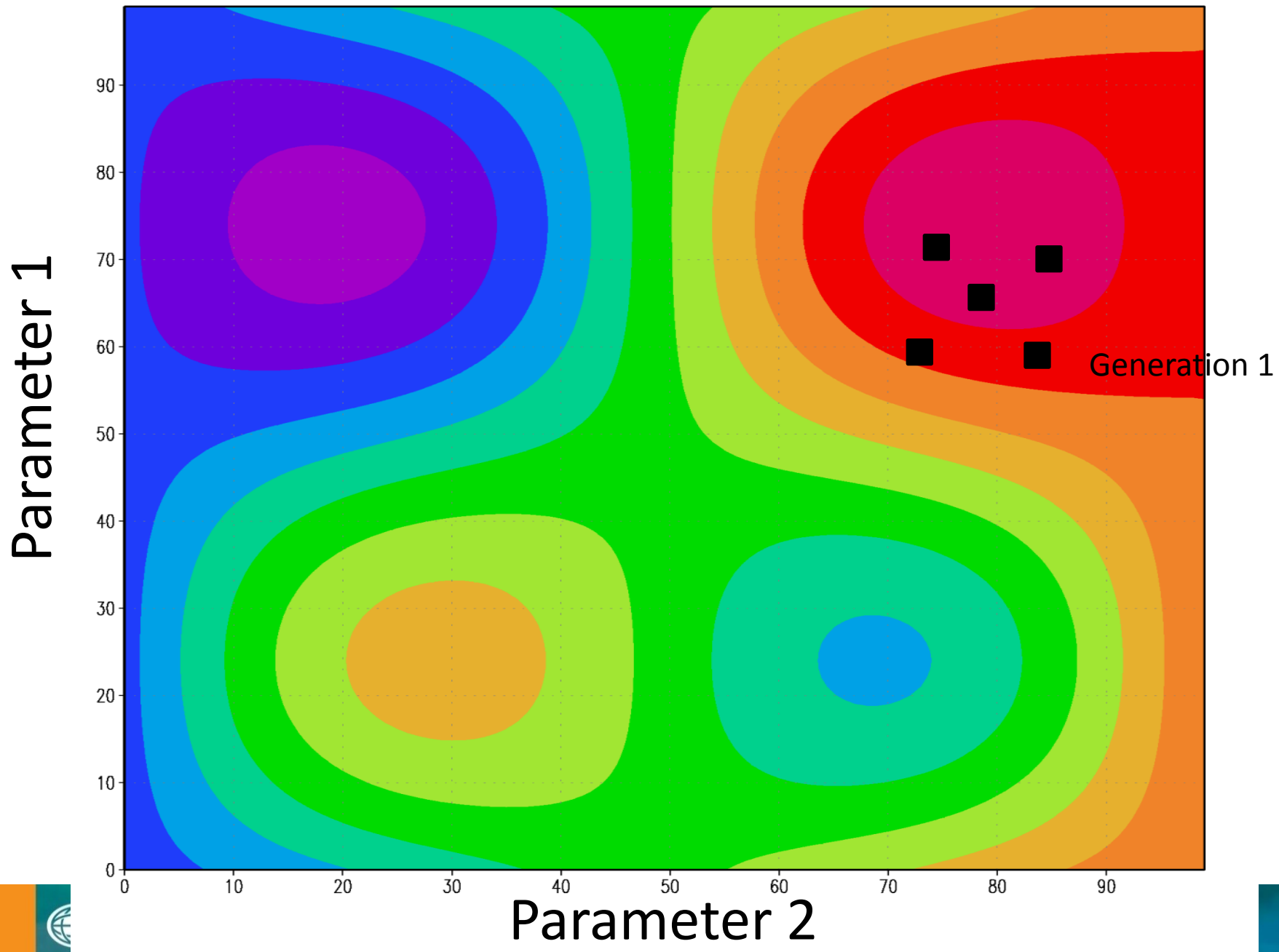
    1. Run multiple simulations of the same event, each using a different parameter set.

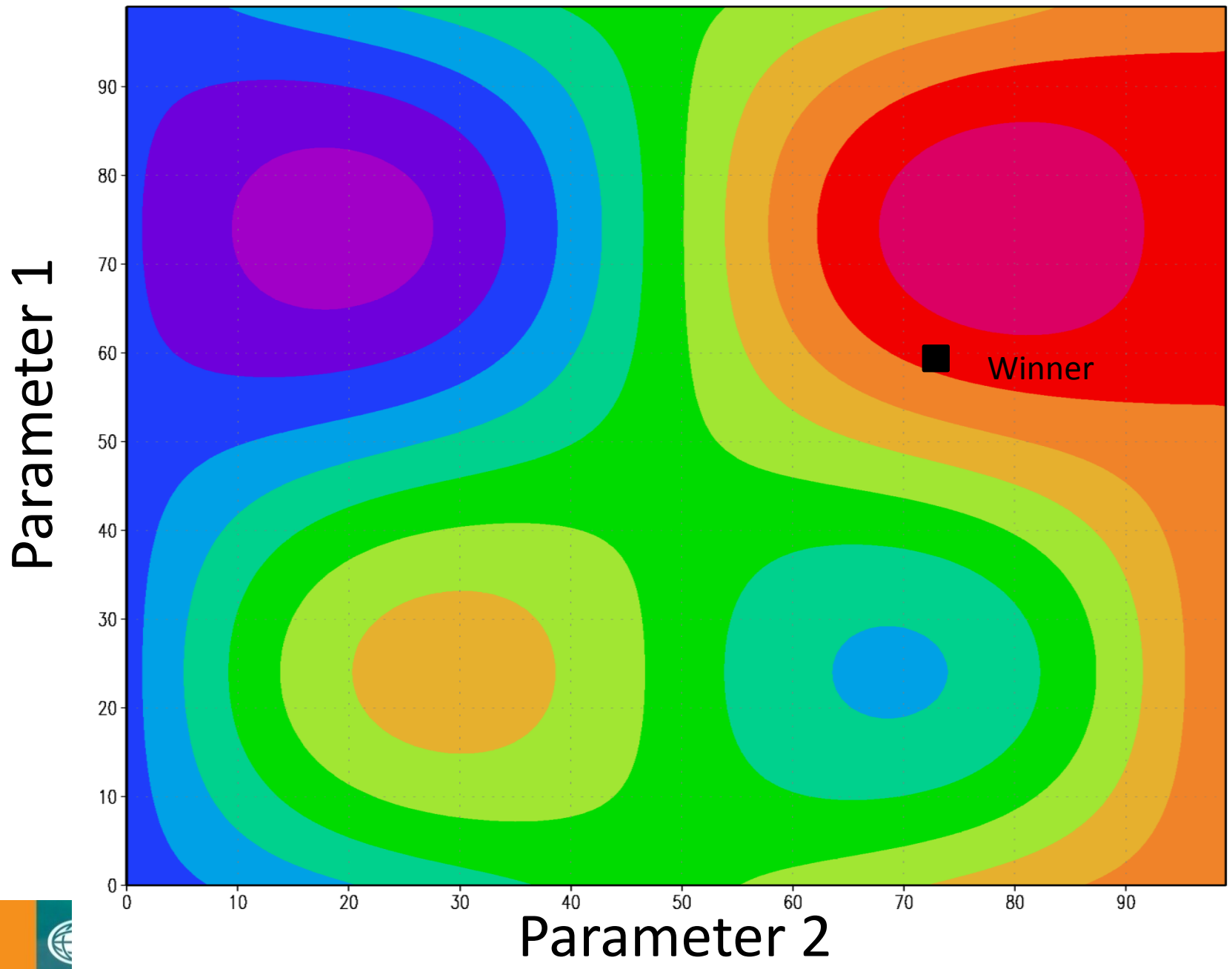
    2. Validate each ‘member’, and select the best.

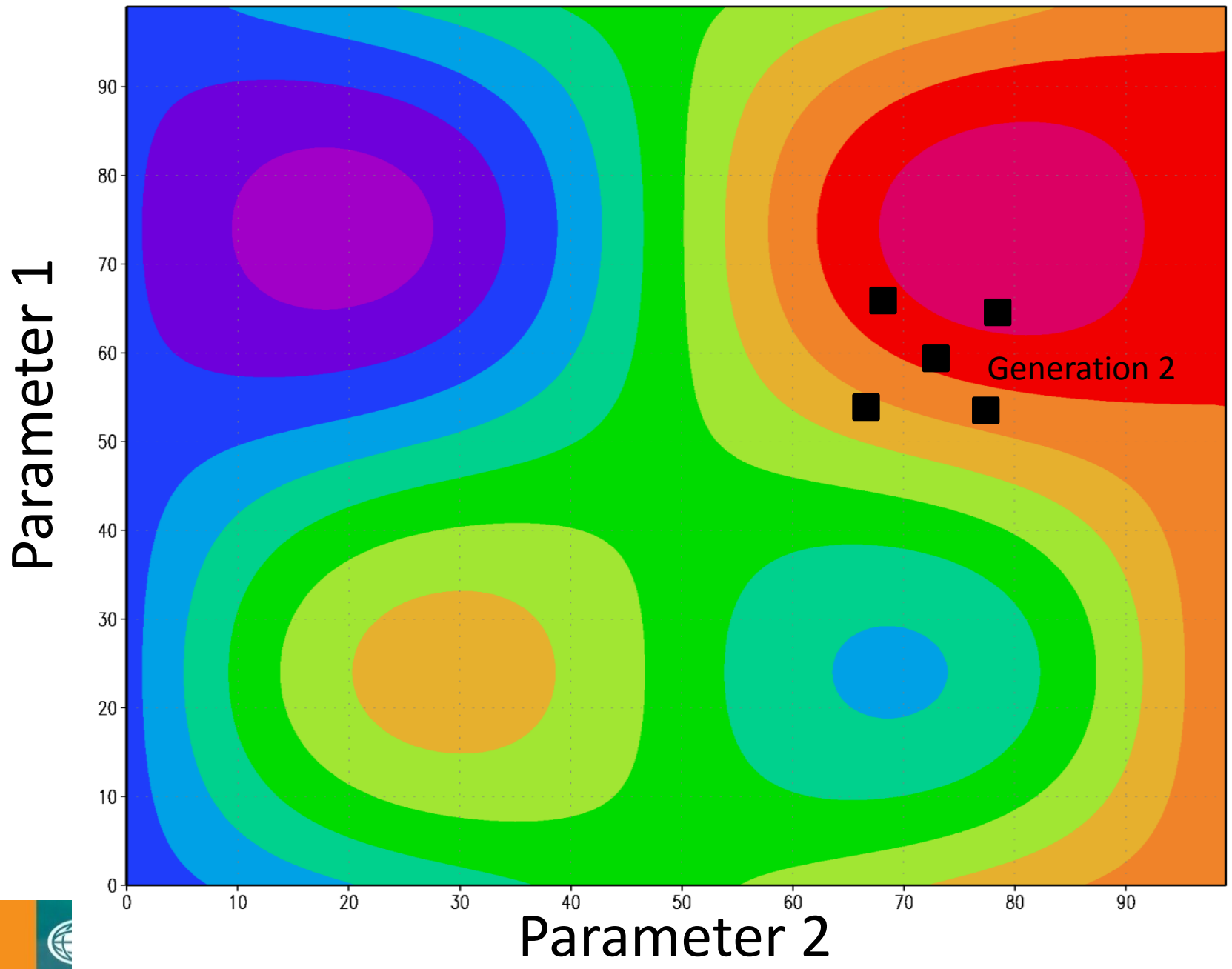
    3. Use that member as the parent of the next generation.

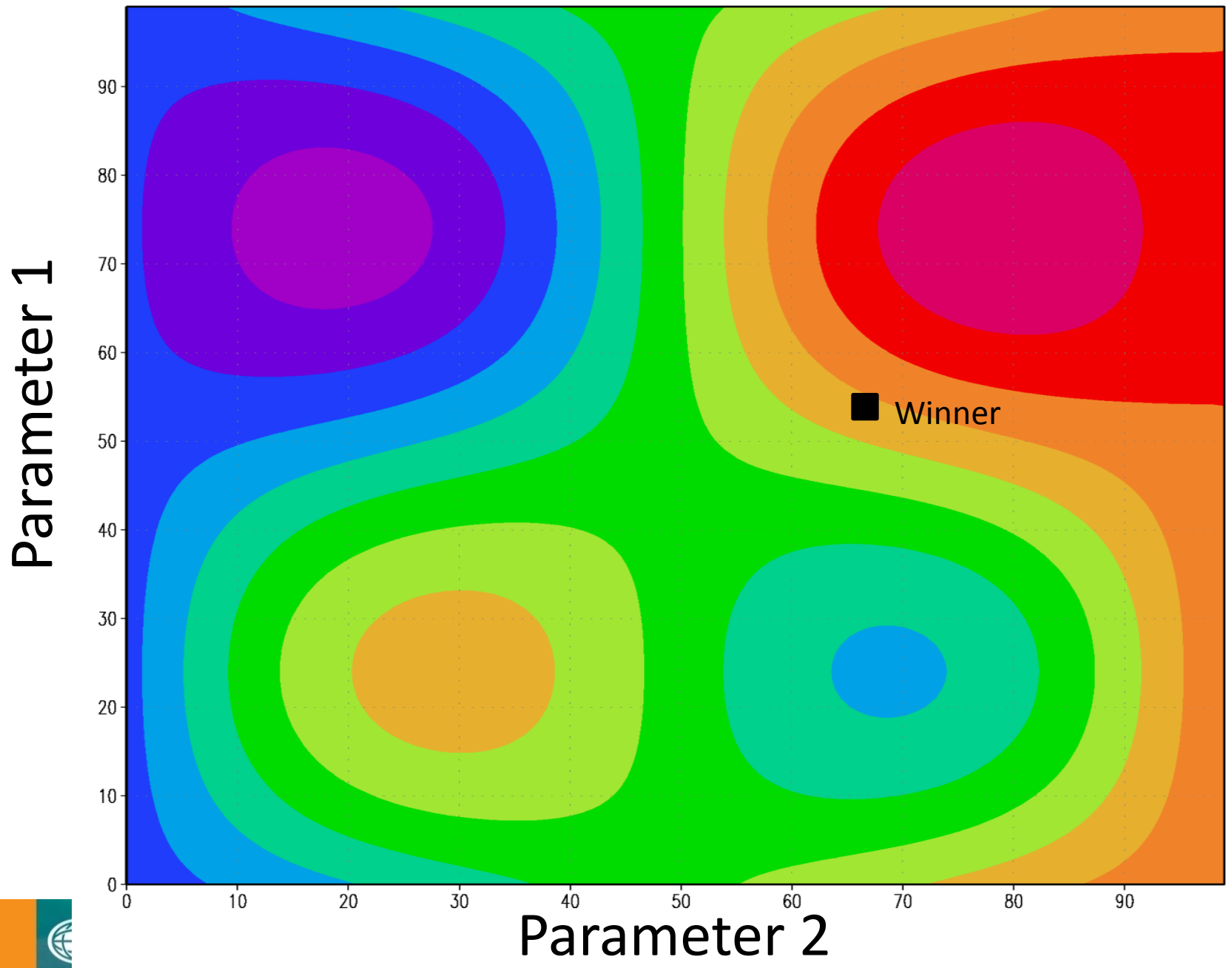

Error
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
100
80
60
40
20
0
Parameter 1
0
20
40
60
80
100
Parameter 2


Maximum Error
Error
Local Minimum
Global Minimum
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
100
80
60
40
20
0
Parameter 1
Parameter 2

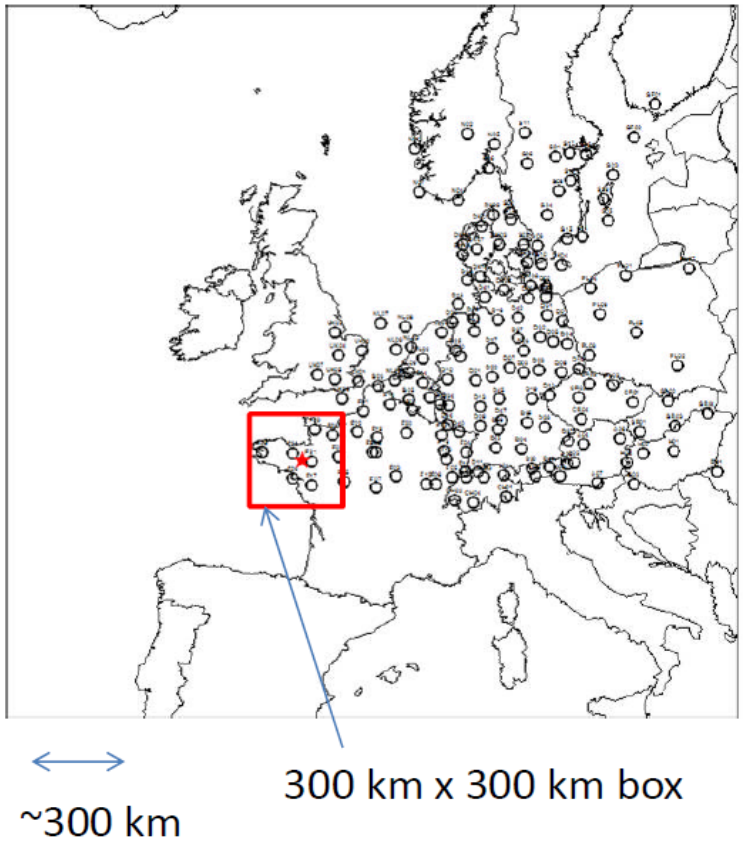

Parameter 1
Parameter 2
Generation 1
0
10
20
30
40
50
60
70
80
90


Parameter 1
Parameter 2
Winner
0
10
20
30
40
50
60
70
80
90


Parameter 1
Parameter 2
Generation 2
0
10
20
30
40
50
60
70
80
90


Parameter 1
Parameter 2
Winner
0
10
20
30
40
50
60
70
80
90

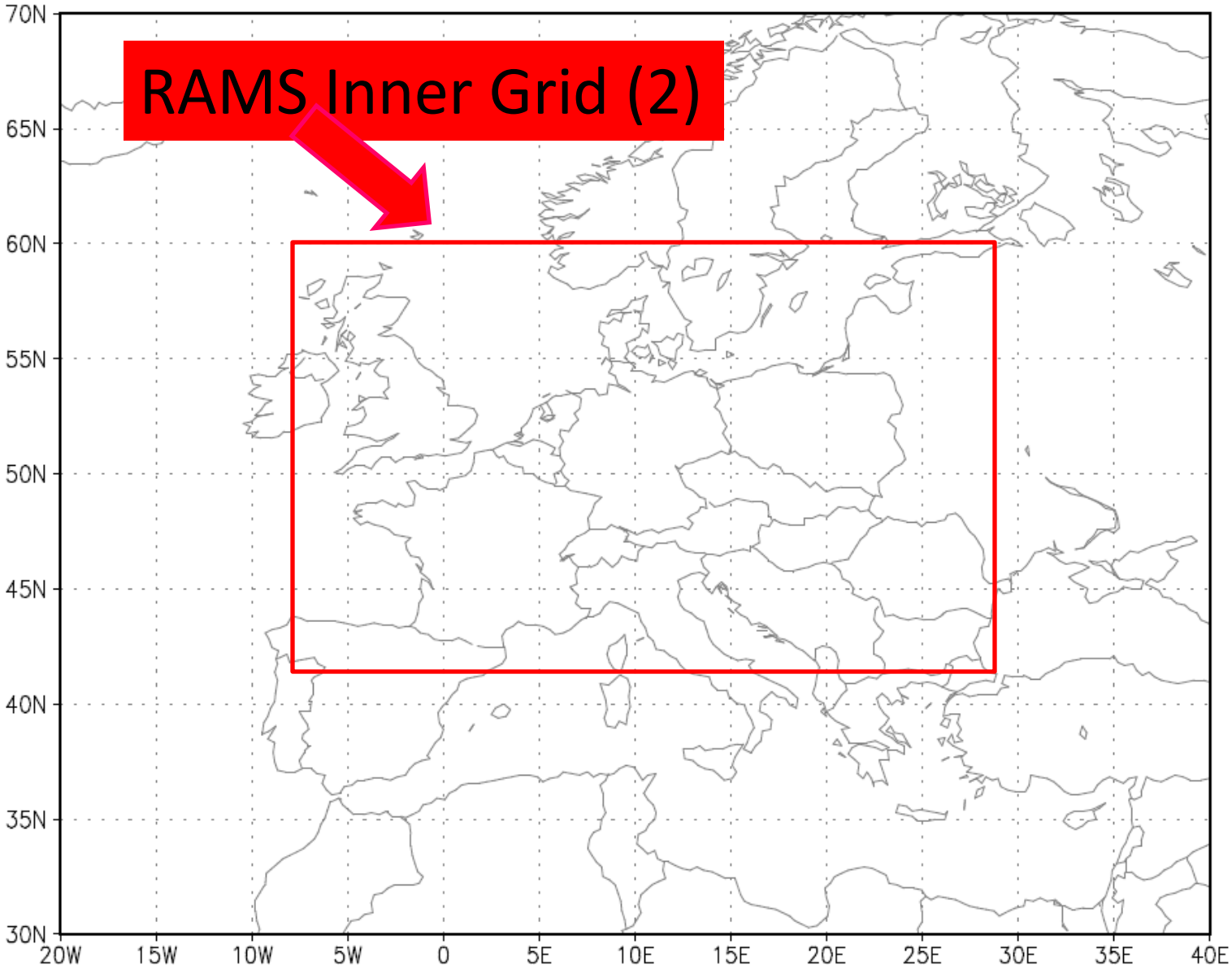
European Tracer Experiment (ETEX)

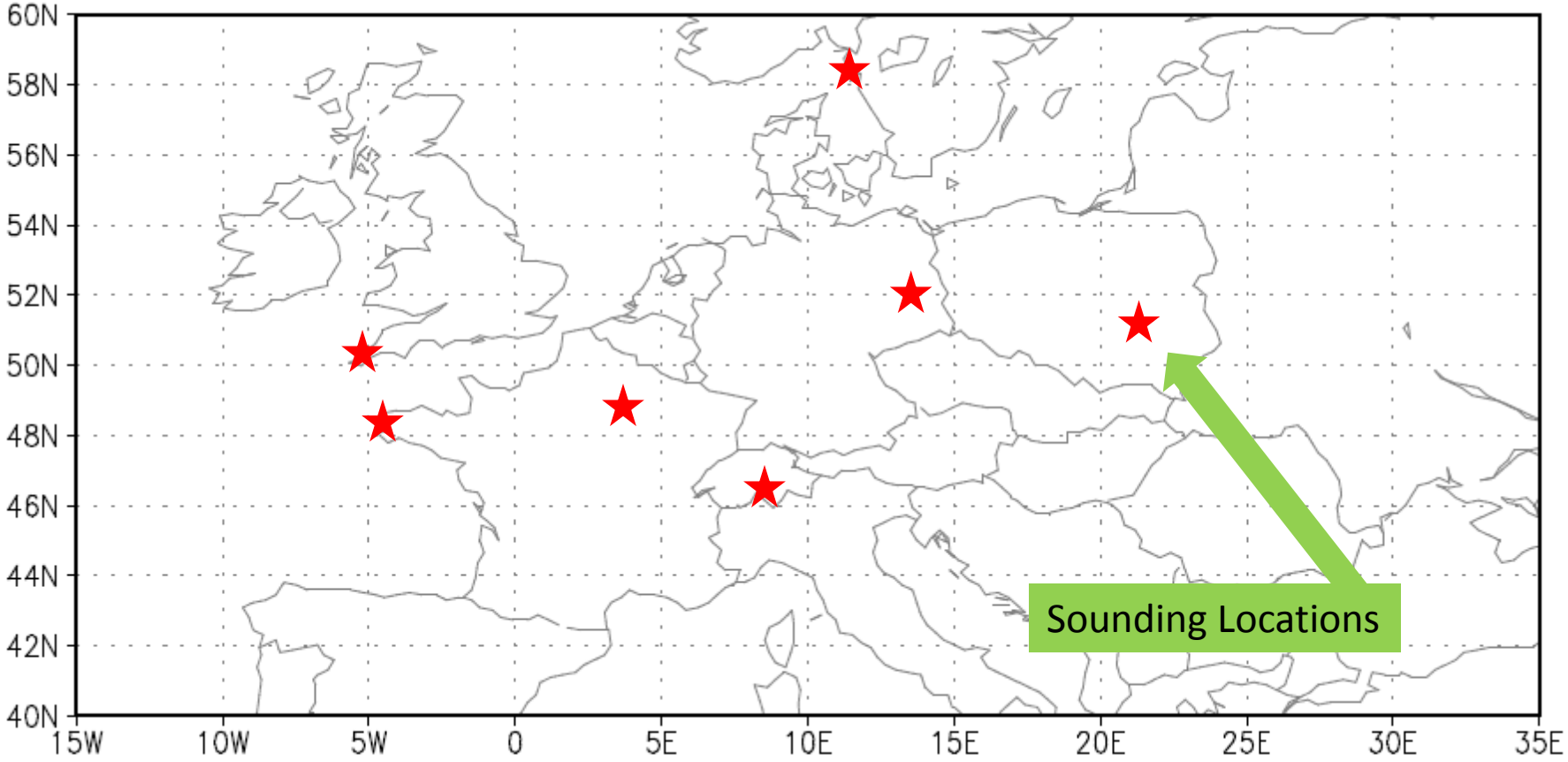


- Designed for emergency response model evaluation
- PMCH tracer release in Oct and Nov 1994 from northwestern France
- 12-hour release starting on Oct 23, 1994 at 16:00 UTC
- 3-hour average samples at various times over 168 samplers in 17 countries
- Most samplers over 300 km away with tracer measured to over 2000 km from release site

RAMS Simulations

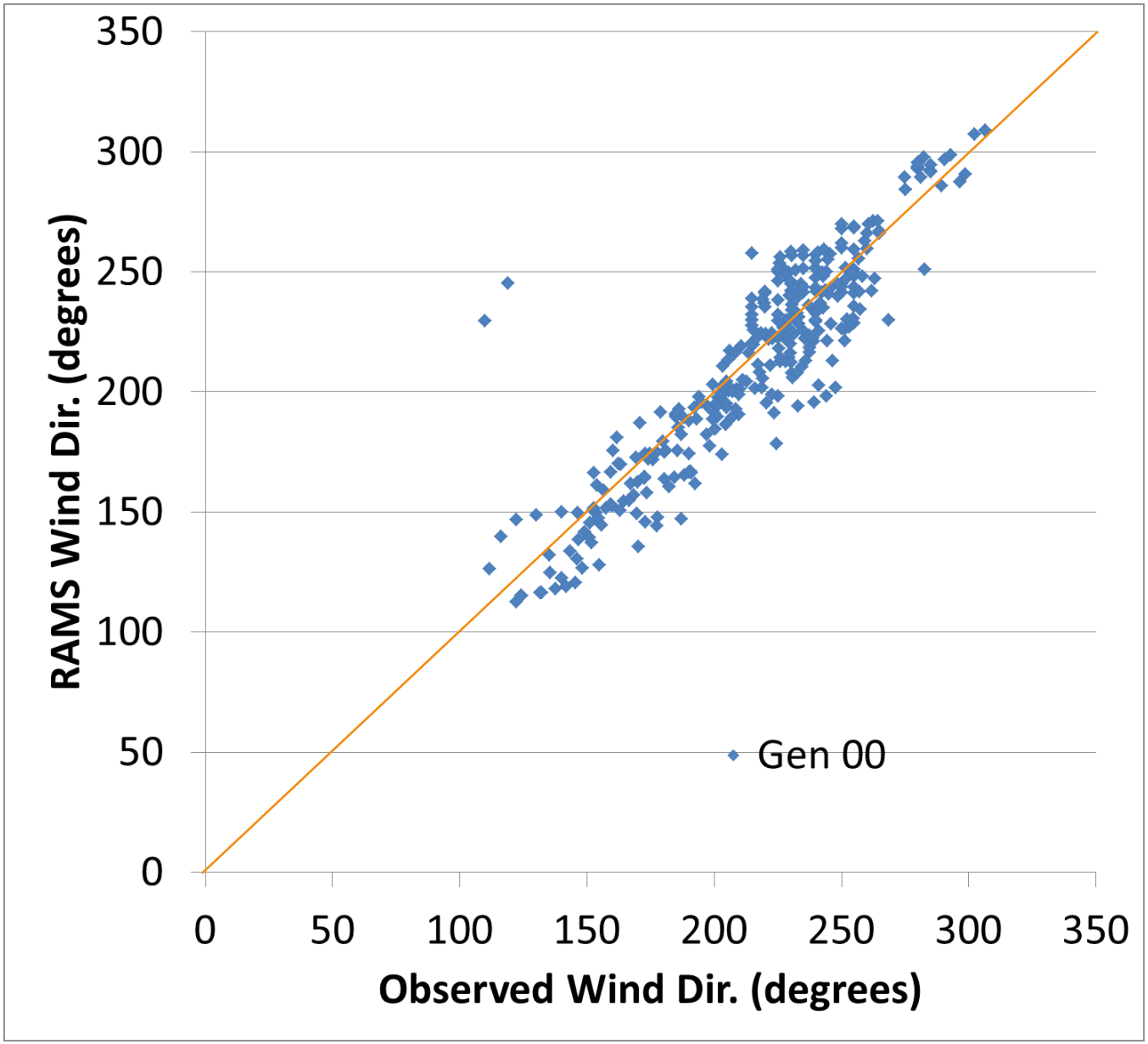
- 60km/20km Grid spacing, nested within 0.5^{o} Climate Forecast System (CFS) data
- Run from October 23rd, 1994, 0000UTC to Oct 27th, 1994, 0000UTC
- Validated against sounding data from the surface to 900mb at 7 locations
- 'Winner' selected according to errors in temperature (T), zonal (u), and meridional (v) wind


RAMS Inner Grid (2)
70N
65N
60N
55N
50N
45N
40N
35N
30N
20W
15W
10W
5W
0
5E
10E
15E
20E
25E
30E
35E
40E

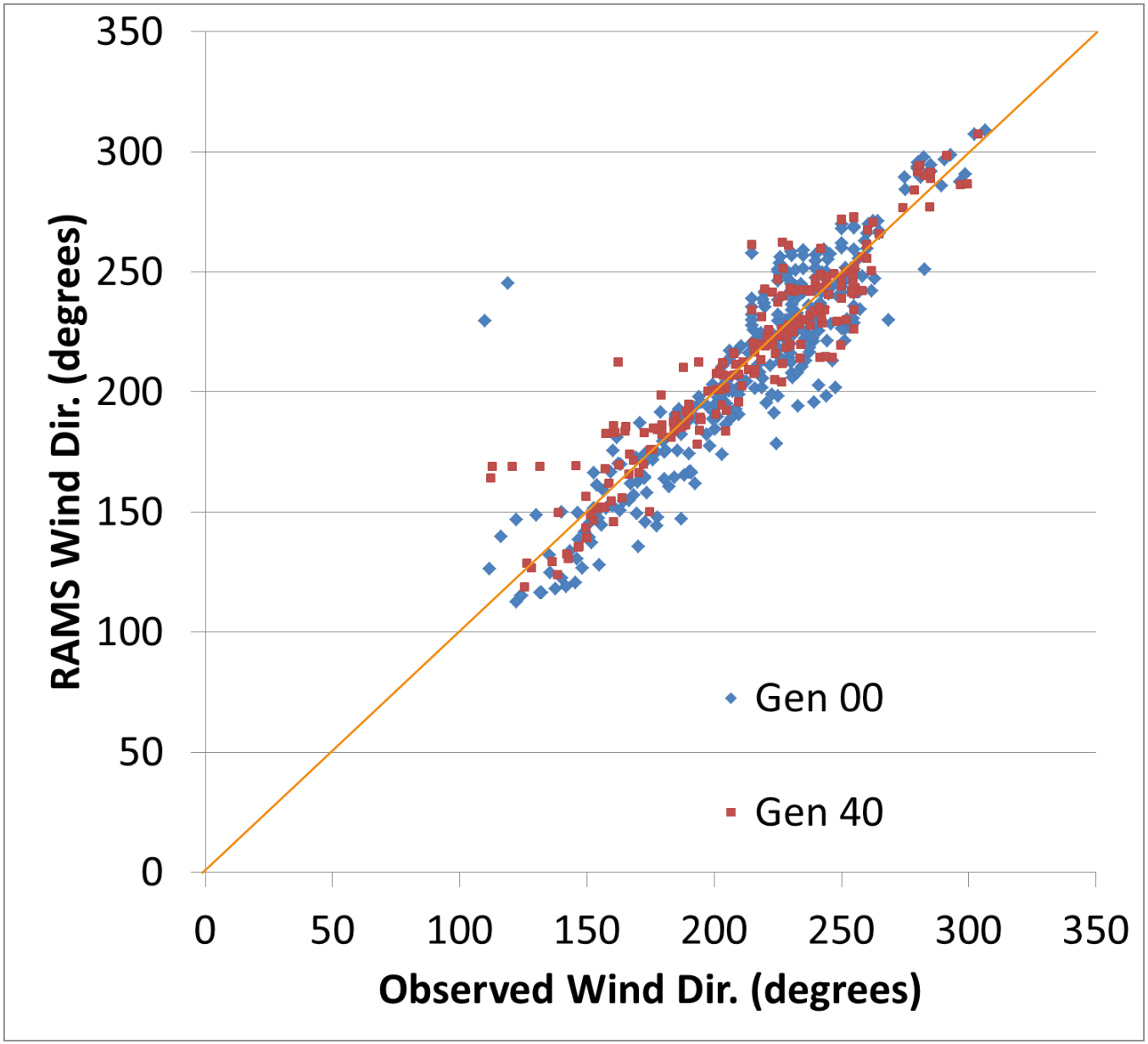

60N
58N
56N
54N
52N
50N
48N
46N
44N
42N
40N
15W
10W
5W
0
5E
10E
15E
20E
25E
30E
35E
Sounding Locations

Perturbed Parameters

1. AKMIN Grid 1 (controls subgrid-scale mixing)
2. Nudging Time at Boundary
3. Nudging Time at Center
4. Initial Soil Moisture
5. Initial Soil Temperature
6. AKMIN Grid 2 (controls subgrid-scale mixing)
7. TOPTENH (controls subgrid-scale topography)
8. TOPTWVL
9. Length Scale multiplier (controls subgrid-scale mixing)



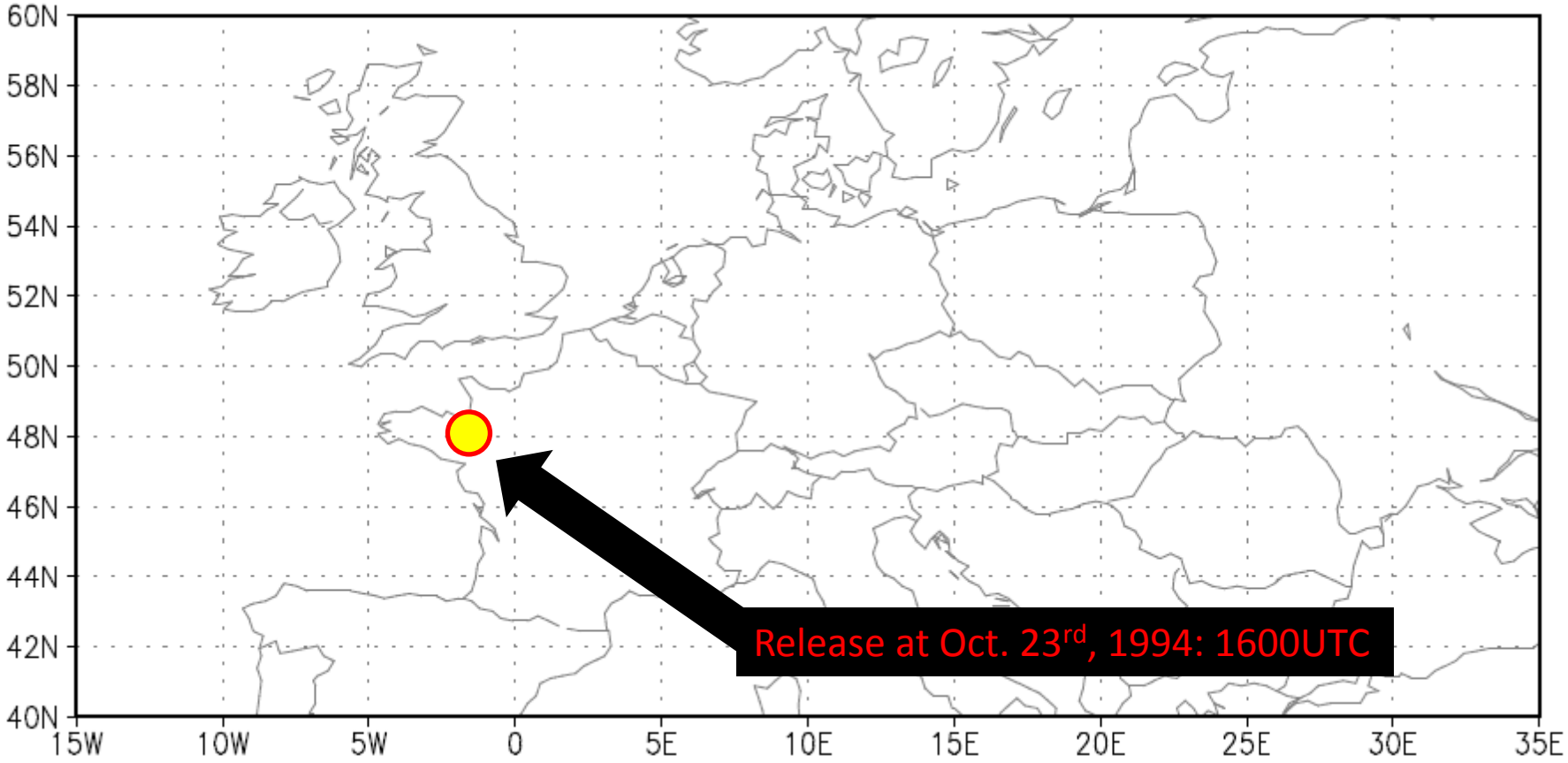
Gen 00: 23% of model values are within 5^{o} of observations



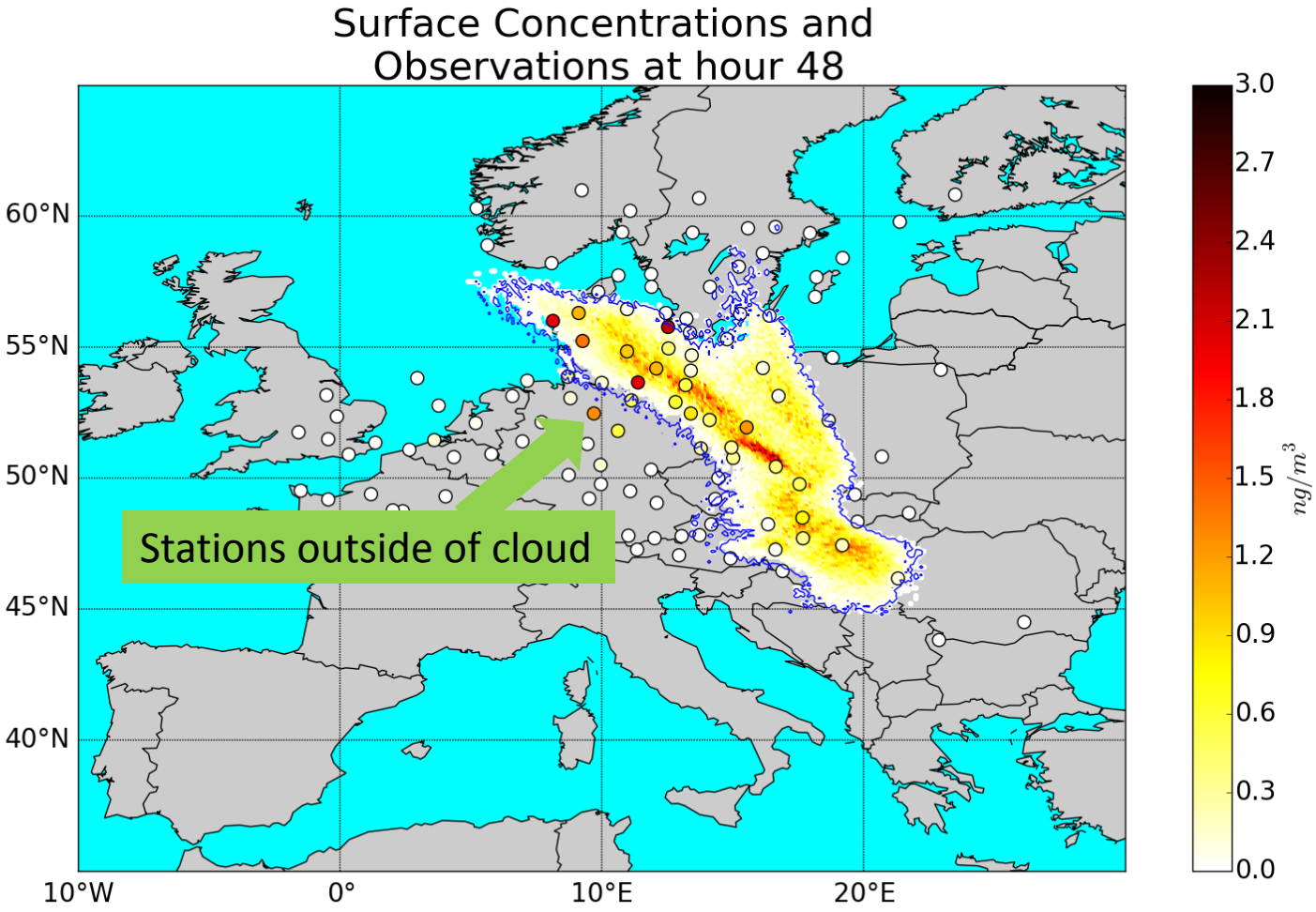
Gen 00: 23% of model values are within 5° of observations

Gen 40: 37% of model values are within 5° of observations

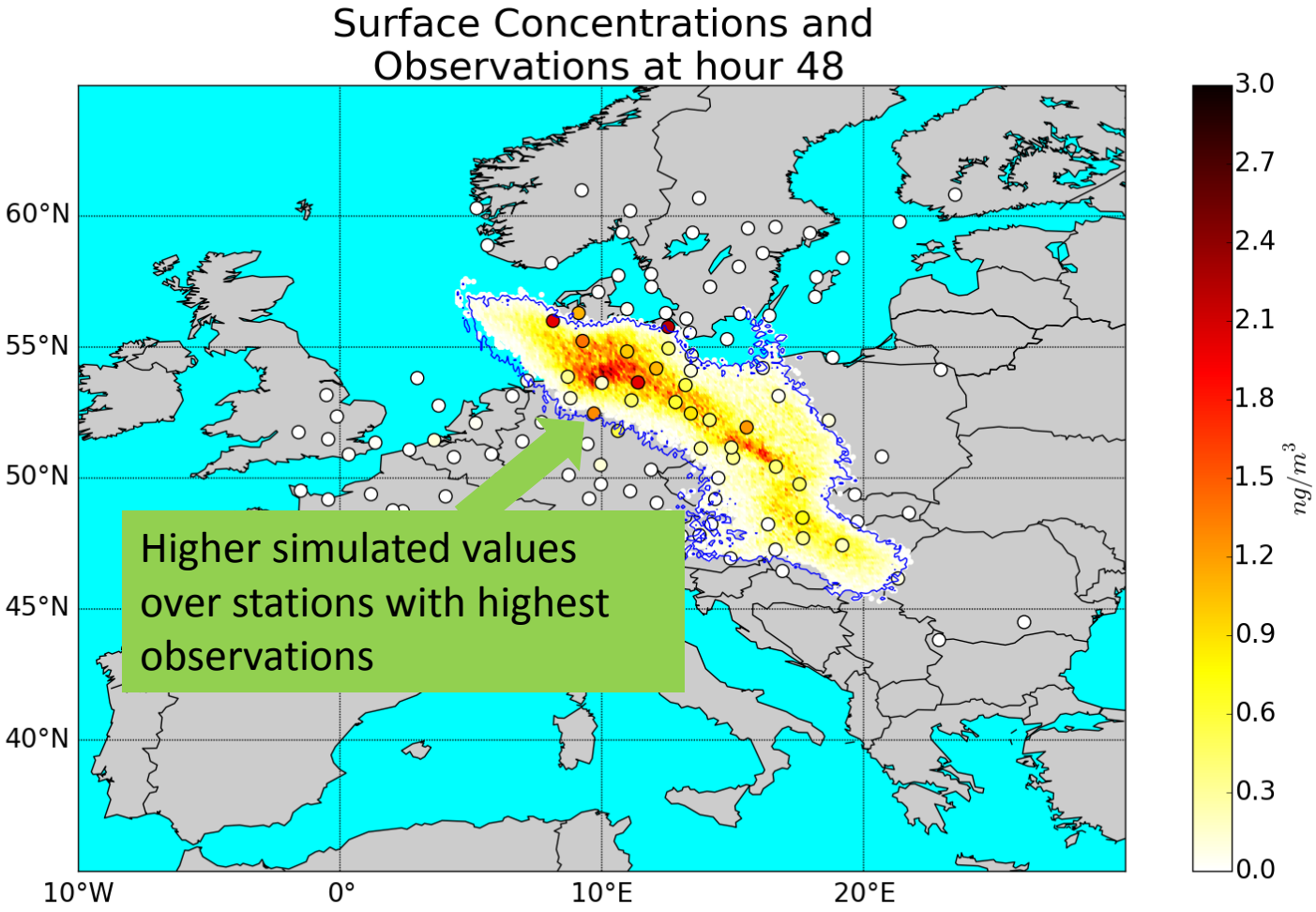
HYSPLIT Tracer Simulation



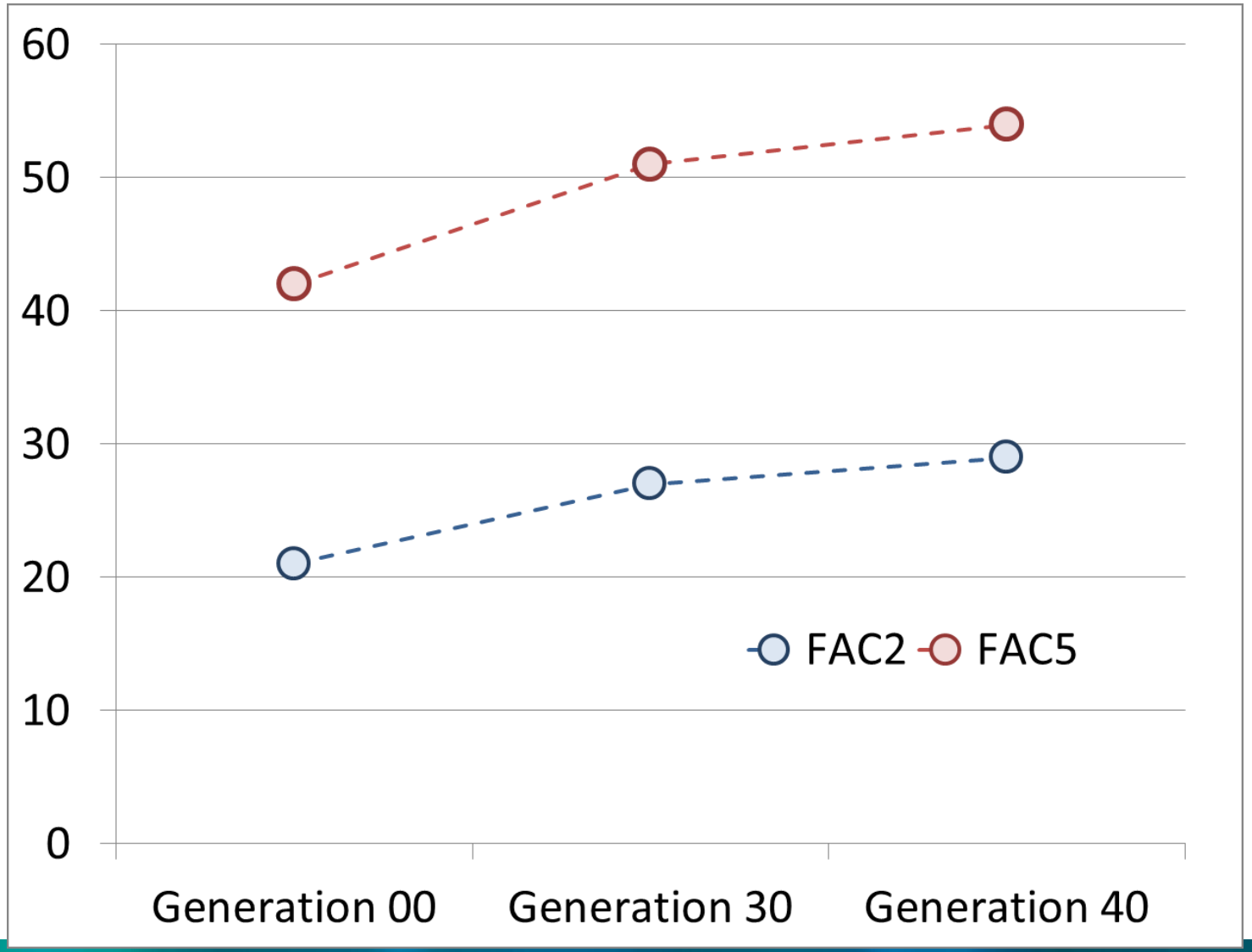
Generation 00



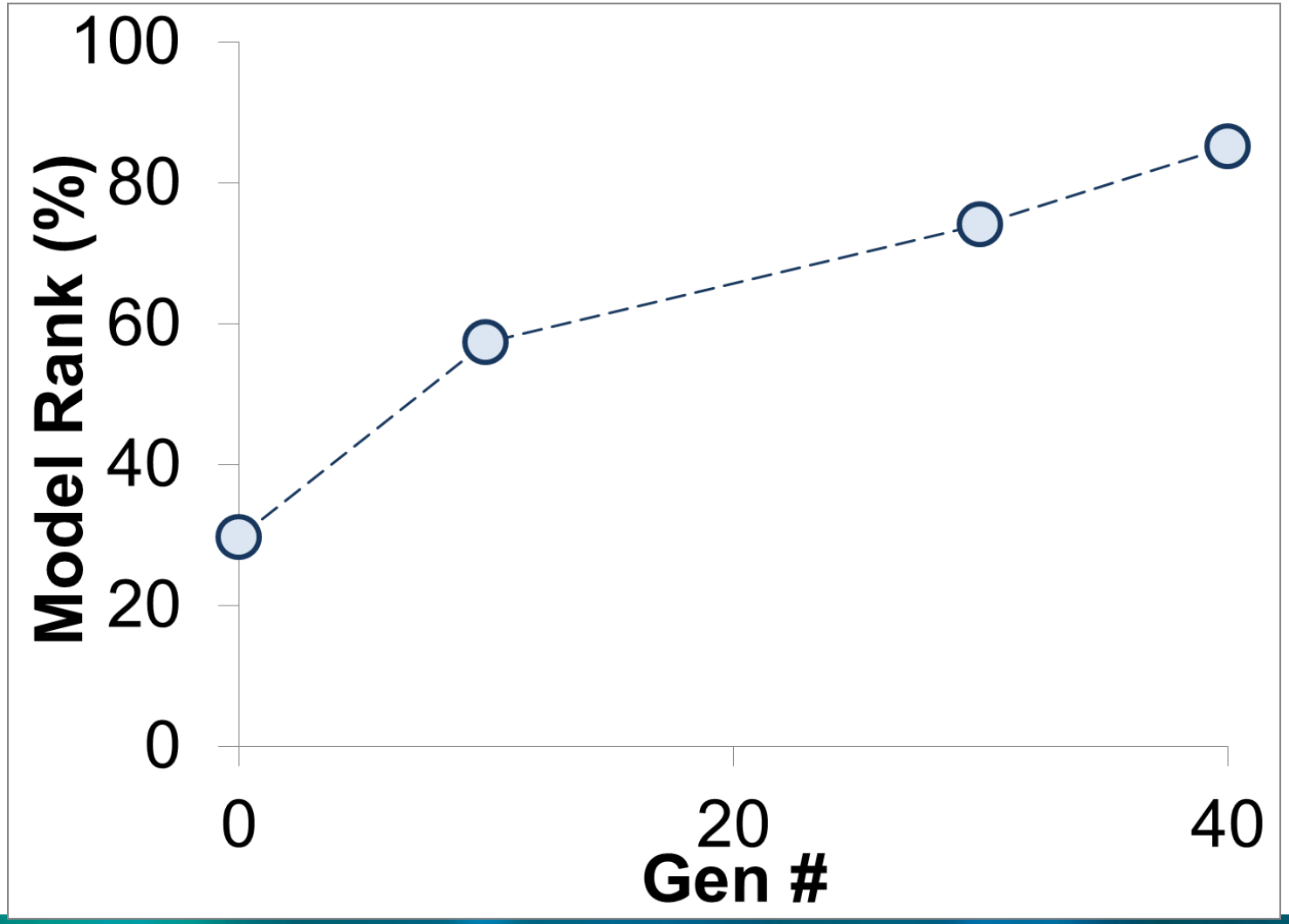
Generation 40



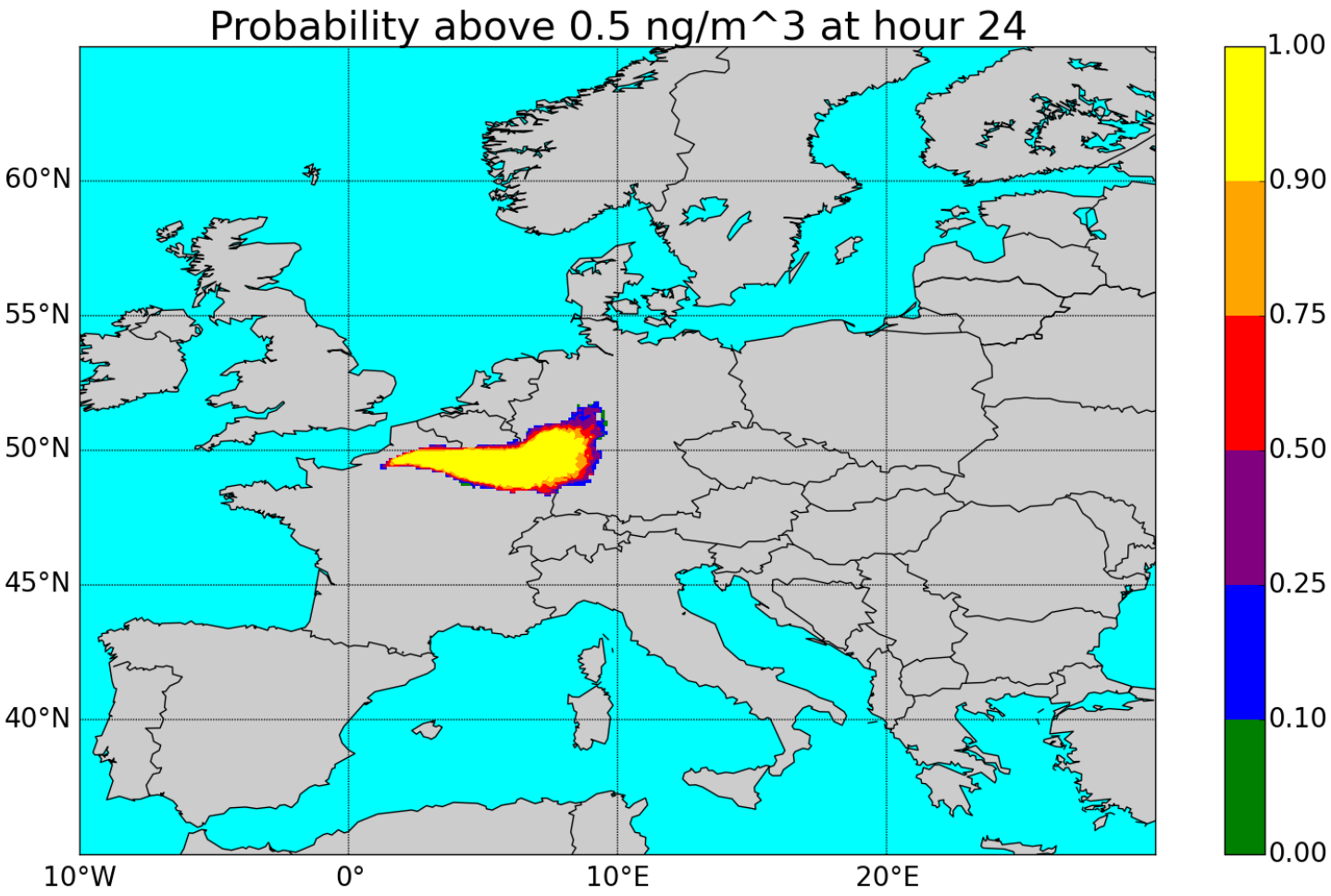
Fraction of simulated concentrations within a Factor of 2 (FA2) and 5 (FA5) of the Observed Concentrations



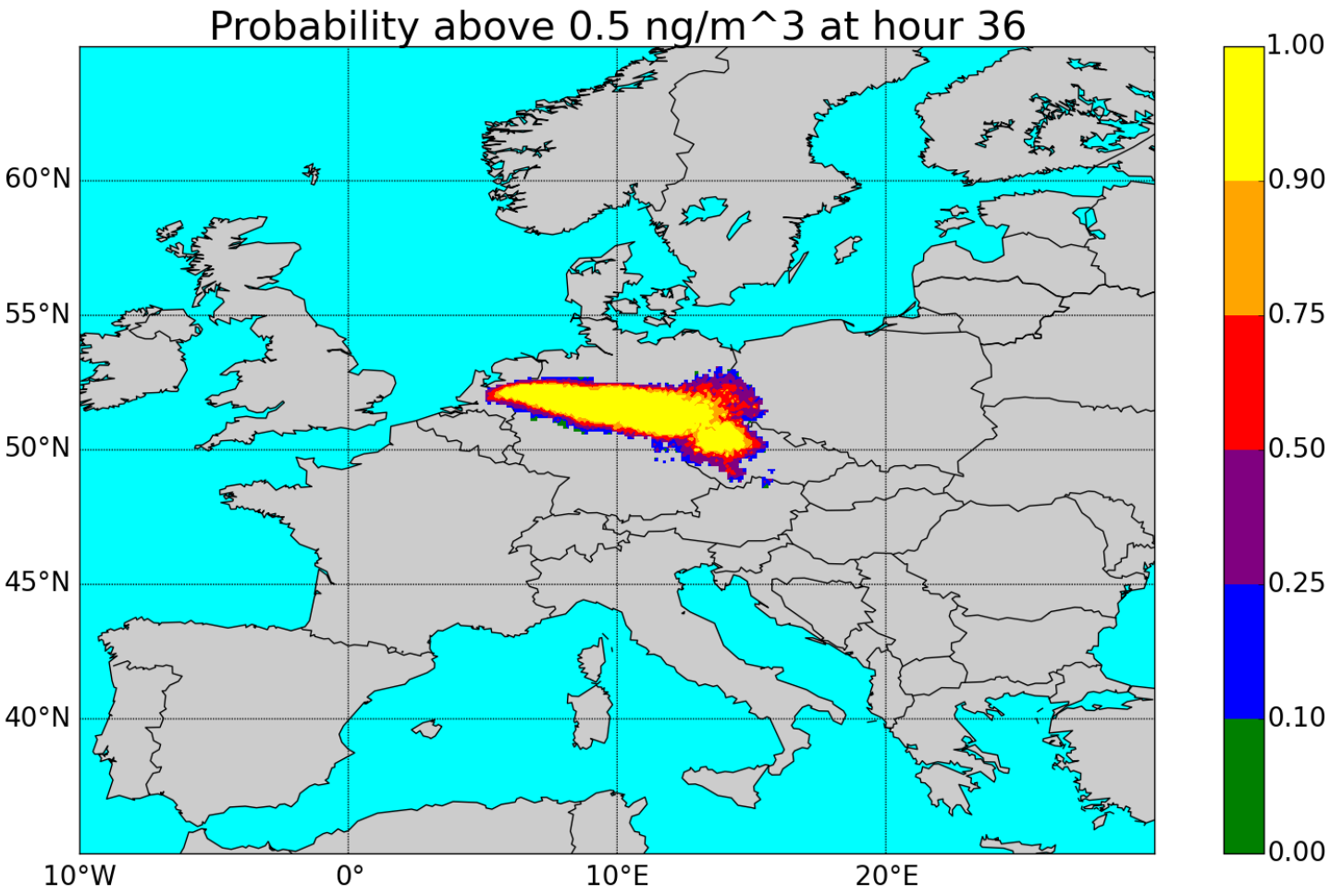
Model ranking relative to simulations from Atmospheric Transport Model Evaluation Study II (ATMES II, 1998).



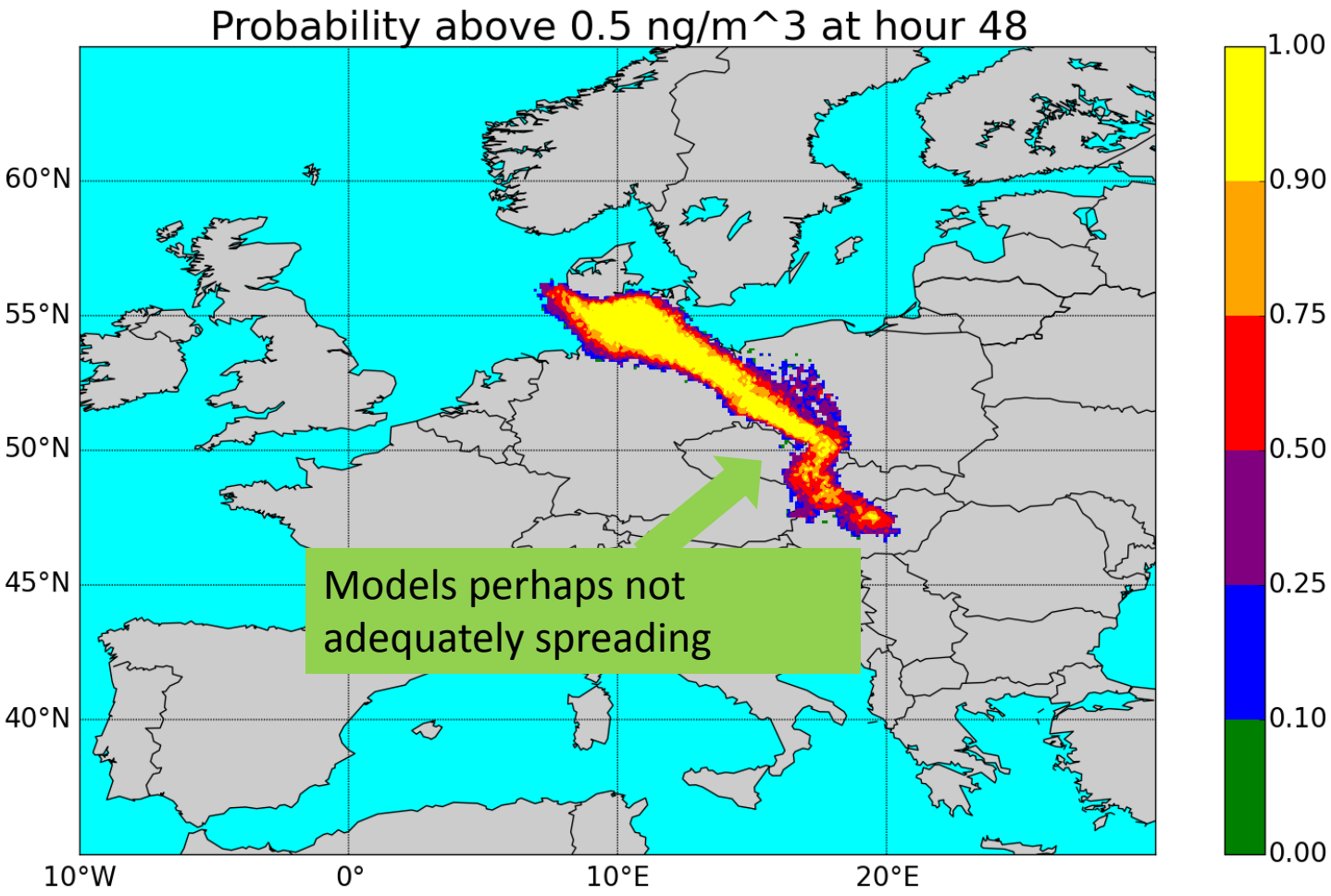
Generation 40 Ensemble Spread



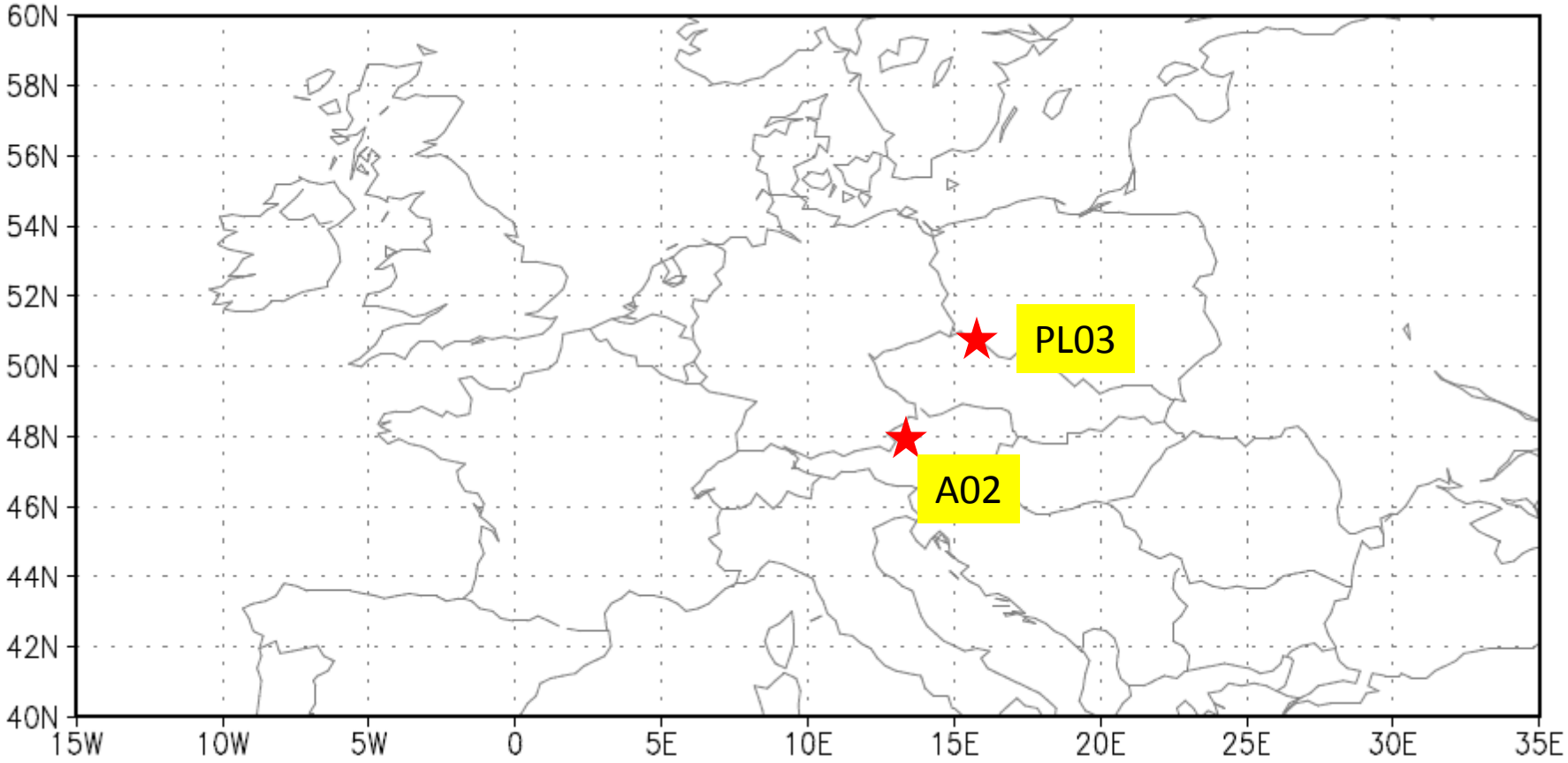
Generation 40 Ensemble Spread

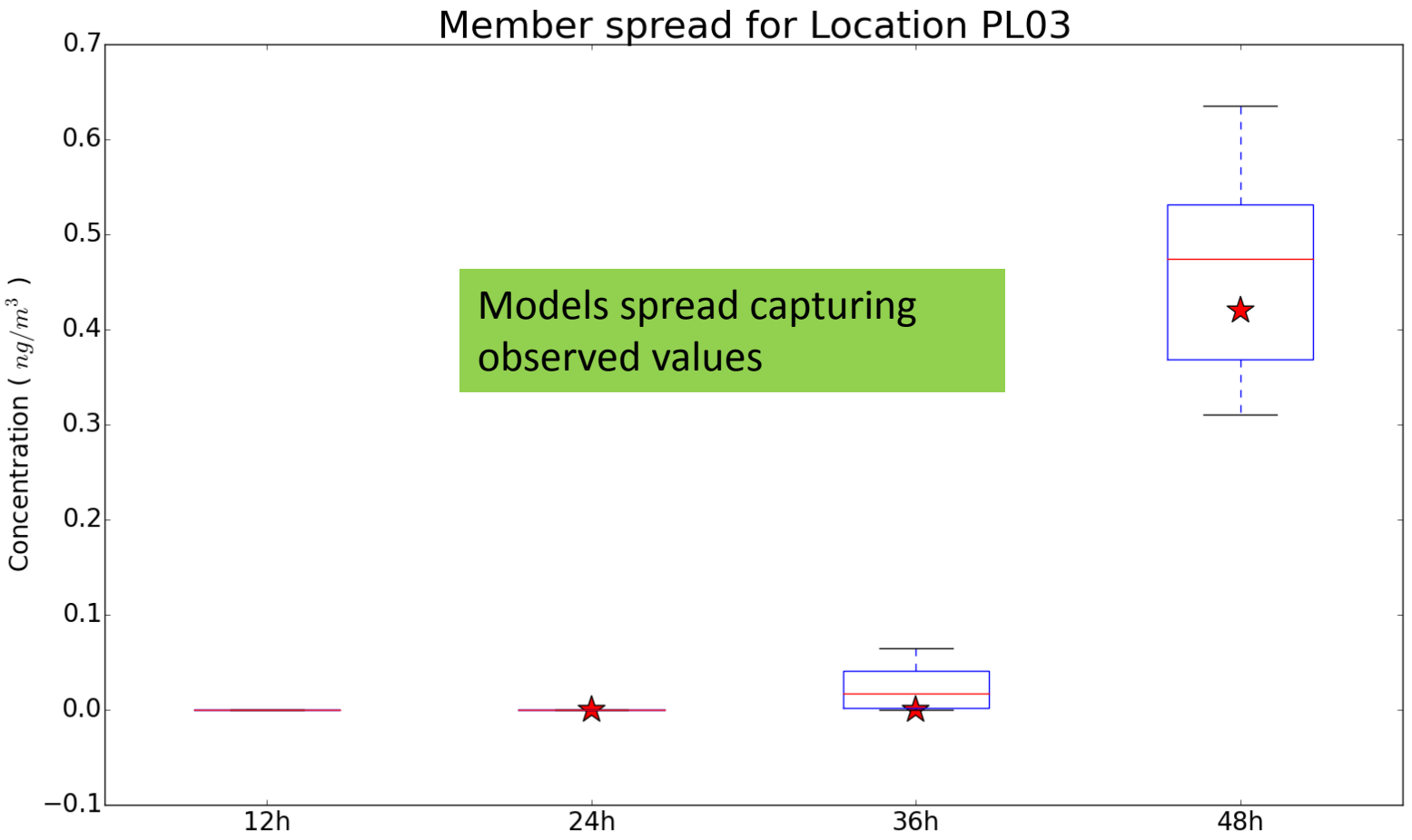


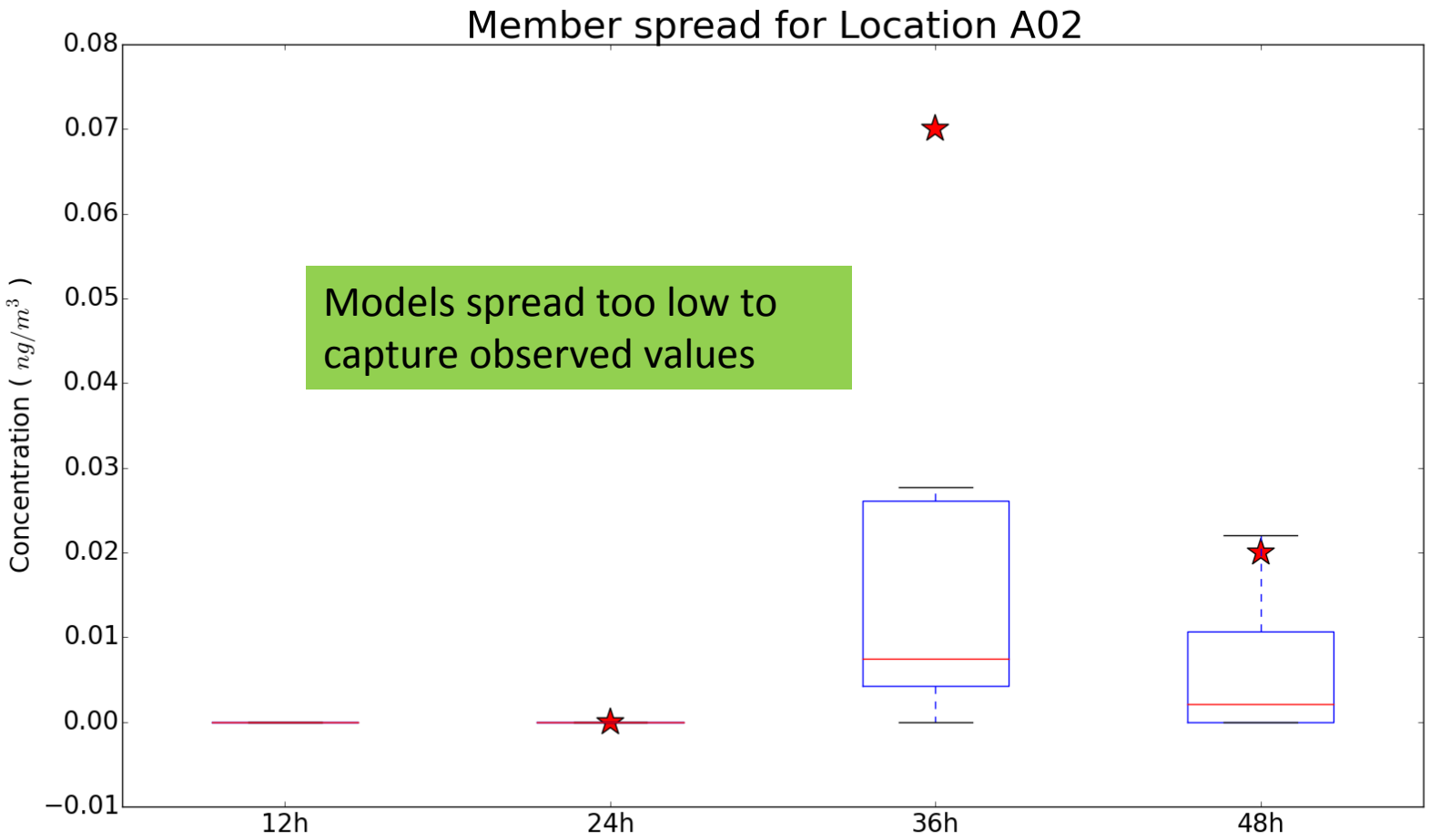
Generation 40 Ensemble Spread



Ensemble Spread




Member spread for Location PL03
Concentration (ng/m^3)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
12h
24h
36h
48h
Models spread capturing observed values


Member spread for Location A02
Concentration (ng/m^3)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
−0.01
12h
24h
36h
48h
Models spread too low to capture observed values

Conclusions

- Adjusting the RAMS parameters led to an improvement in the meteorological model simulation
- After assimilation of wind data from 7 European sites, SRNL's skill score for ETEX improved (according to objective metrics) from a rank in the bottom 30% out of the 50 evaluated transport models to the top 15%.
- This process can significantly improve a post-analysis dispersion simulation

Future Work

- Apply an ensemble-Kalman filter to the ETEX experiment, for comparison to the adaptive programming ensemble

- Extend both ensemble methods to a smaller-scale, complex terrain situation - the tracer-release field project at Diablo Canyon, California

- Adaptive-grid techniques (i.e. finer resolution over source locations and areas of steep gradients) will be explored as a means of reducing the calculations.